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A Locally Developed Solar Pump Controller

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Abstract*: *This paper describes a locally build up a three phase induction motor controller for a solar powered water pump. In many areas of Bangladesh huge amount of water is required for residential and industrial activities. Agricultural production requires also adequate supply of water but due to scarcity of electricity, this sector is facing significant damage of production. In this case, solar power can be an alternative of grid electricity. For solar irrigation DC motors have been used in Bangladesh because of their easy torque control and speed control. Compared to AC to motors, DC motors are very costly and they require regular maintenance of the commutator. A three phase induction motor does not require brushes and they can be run smoothly in the field. A three phase induction motor capacity of 750 W was successfully run with a prototype setup and a three phase inverter with low cost gate drive circuit. The control strategy integrates MPPT and space vector modulation (SVM) algorithm technique. Discharge rate of this pump is 1200 liters per hour and it satisfied the demand with good efficiency

Index Terms*: DC motor, 3 phase induction motor, MPPT, Space vector modulation (SVM), Inverter.

I. INTRODUCTION

Water is essential for human needs. Water is required for irrigation, residential and commercial activities. Although, more than one billion human beings do not have water in proper conditions for consumption [i].Photovoltaic system is suitable for the development of agricultural and livestock project in remote areas where construction of transmission line is very difficult [ii] .In Bangladesh DC motor has been used for a long time due to its speed control facility [iii], but this DC motor is very expensive. Furthermore, DC motor requires regular maintenance of the commutator.
The solar powered irrigation system has not yet produced significant headway in Bangladesh as it can be seen in figure 1. Now the total requirement of irrigation pumps run by electricity or diesel is about 1.61 Million (as of 2015).The total number of pumps installed by IDCOL are approximately 200. Although, IDCOL provided 40-50% incentive with 35-40% soft interest loan the number of PV operated pumps is insignificant. All of these projects, already in operation, but those are totally based on expensive imported technologies [3]. Sometimes imported technology restricts the multipurpose use of pumping system at different sectors (driving AC motor in industries or households) throughout the year. Due to the import of major components, there is cost imbalance, shortage of after sale service and so on.

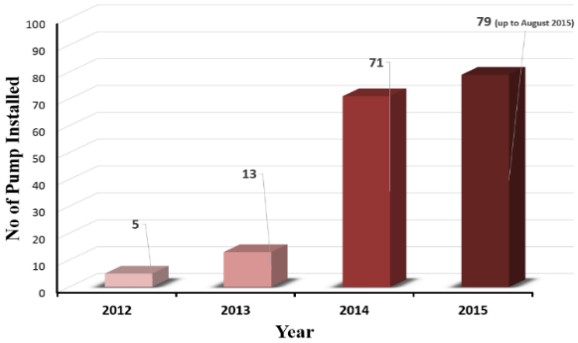

Figure 1: No of pump installed by IDCOL from 2012 to 2015 [iv].

The pump-controller-inverter system cost is approximately 30-50% cost of the total project cost [v]. These parts of the project are totally imported equipment and these equipment restrict the engineer to implement innovative ideas during project design phase, and also maintenance during operation period.
To overcome this problem, a prototype three-phase AC motor drive system has been locally developed at the Institute of Energy, University of Dhaka. The newly developed portable three-phase AC water pumping system with micro-controller based control system would be able to serve the multipurpose irrigation as well as operating in other sectors where AC motor operation is already in use. The power provided by 1KW solar panel is adequate to drive a .75 KW HP three phase induction motor.

II. PHOTOVOLTAIC WATER PUMPING SYSTEM

In solar pumping stand -alone system all power is delivered by the solar panels. The converter maximize the input power through the MPPT algorithm [vi].
In this research work, asynchronous induction motor has been used with the pump. Theoretically the basic idea is simple. We have designed and developed the VFD with high efficiency. There are three different types of VFDs: • VSI - Voltage Source Inverter, e.g. PWM. • CSI - Current Source Inverter. • Flux vector control.
The CSI has a rough and simple design and is considered to be very reliable, but the output signal means a lot of noise. Furthermore the CSI induces high-voltage transients in the motor. The flux vector control is a more sophisticated type of VFD which is used in applications where the speed should be controlled very precisely, e.g. paper mills. This type is expensive and pump applications cannot take advantage of its benefits. The most common type of VFD and the one that will

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be developed in this project is the PWM – Pulse Width Modulation. The PWM-type VFD normally uses a constant voltage. The PV array works as constant voltage source beyond the MPP point.

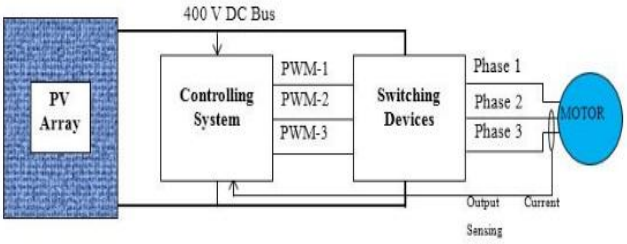
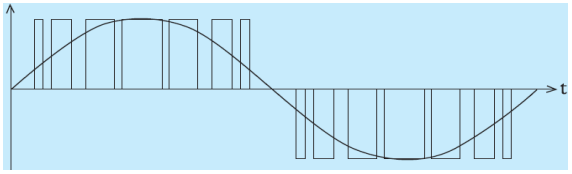
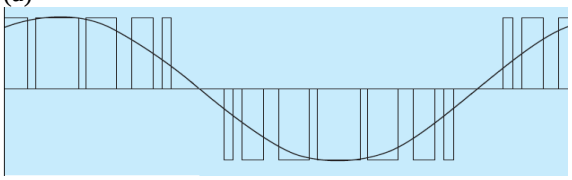


Figure 2: Block diagram of the proposed system.

The microcontroller (dsPIC30F2010) will control the entire system. It will generate the three-phase PWM signal. The PWM signal will drive the power switches. In this project IGBT module (STGIPL 14K60) will be used as power switch. The IGBT module can tolerate 600V and 30 A. The width of the PWM pulses will be pre-programmed so that pure sine waves are produced. The switching frequency of the IGBT will be very high (16 kHz, 1024 samples per cycle) to reduce harmonics. Three groups of PWM signals will be developed by the microcontroller. There will remain 120° phase difference between successive groups of PWM which are shown in below



(a)



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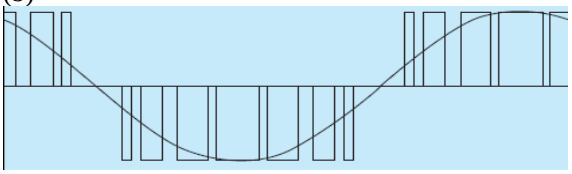

(c)

Figure 3: Diagram of PWM pulse groups (a) pwm-1, (b) PWM-2, (C) PWM-3

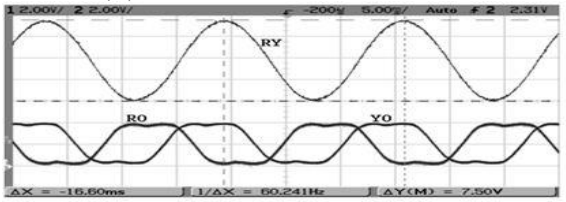

Figure 4: SVM generated wave form.

Figure 5: Practical operation of solar pump

At the output of the IGBT modules the pulses of the PWM groups will be filtered and pure sine wave will be developed. The nominal output frequency of the three-phase AC will be $50H_Z$ as shown in Figure. 7. But this frequency will be variable from $5H_Z$ to $75H_Z$. The variation in frequency will be achieved by changing the total time of the PWM pulse groups. The controlling unit will always monitor the output of the PV array and the output AC current for short circuit protection. If the output power from the PV array is low then, its output voltage will also be low. Then the controlling unit will decrease the output frequency and hence the motor will run slowly. The pump will deliver water at a lower rate. But when the output power from the PV array becomes high, the output voltage of the array will also be high. Sensing this high voltage the controlling unit will increase the output AC frequency. Hence, the motor will run with higher rpm and the pump will deliver water at a higher discharge rate. Thus the system will automatically adjust its operating frequency. At lower output of the PV array, although, the rpm of the motor decreases, the torque remains almost constant to provide the required head to lift water. The system will always monitor the output AC current to provide over load control and to protect the VFD and the motor from being short circuit.

III WATER PUMP CONSIDERATION

The control system is a microcontroller based (Microchip dsPIC 30F2010) 3 phase Variable Frequency Drive (VFD) high efficient ac motor control system using Space Vector Modulation (SVM) topology.

Overall System Specification:

Water pump:

- Type: 3- Phase Induction Motor
- Capacity: 0.75 KW (1 HP)
- Operating Voltage: 380- 440 Volt
- Operating Frequency: 50- 60Hz
- Pump Capacity: 3-7m Head
- Discharge Rate: 1200 L/hr

Controller:

- Type: 3- Phase Inverter
- Maximum Input: 600 Volt DC
- Output: 380- 440-Volt (AC) 3-φ
- Controller: dsPIC Microcontroller (Microchip)
- Algorithm: Space Vector Modulation (SVM) Algorithm Technique
- Output Frequency Range: Variable Frequency Drive (VFD) from 5 to 200Hz

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- Modulation: 16KHz PWM (Pulse Width Modulation)

Solar panel:

- Type: Poly- Crystalline
- Number of Panel: 18
- Total Wattage: 1KW

IV ESTIMATED IRRIGATION OF LAND AREA

Flow rate of The Pump at 70 W/m2 Radiation of 1KW Array System = 1200 l/hr = 0.42l/second**.**

- 120 days irrigation period.
- 12 hours a day

Total discharge during irrigation period

$$\frac{0.42 \times 60 \times 12 \times 120}{1000} \text{ M3}$$

=2177.28 M3

TATBLE 1 NAME OF CROPS AND REQUIRED WATER VOLUME [vii]

Name of the crops	Required Water Volume (m^3/hectare)	Average (m^3/hectare/year)	Average (l/hectare /month)
Rice	850	750	62500
Wheat	700		
Cotton	700		

$$\text{Area irrigated} = \frac{\text{Volume of availabe water}}{\text{Volume of water required/ha (M3)}}$$

$$\frac{2177.28}{850}$$

=2.561 hectare land can be irrigated

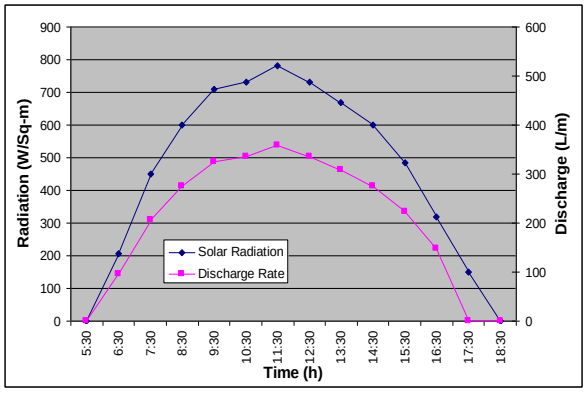

Figure 5: Graph of solar radiation and water discharge rate.

The performance of the system has been studied in the Institute of Energy, University of for Dhaka some days.

- Efficiency of the overall system: **45 %**
- Threshold Solar Radiation: **200 W/m^2**
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V CONCLUSION

The cost of the solar irrigation pumping system needs to be reduced drastically to increase no of installation significantly. This is only possible if the pump-controller-inverter system can be developed locally. The developed VFD has some special features. It can run both induction motor for water pumping and PM (permanent magnet) AC motor for compressor of Air Conditioner. In this high efficient driving system the DC output of the panel has been converted into three-phase AC voltage of 220 volt but of variable frequency. The range of the output frequency is from 5 Hz to 200 Hz. Although, induction motor for water pumping can operate up to 60 Hz maximum, the compressor motor can run up to 200 Hz input. One of the important features of this system is to sense the available output current from the PV panel and to adjust the operating frequency. If the output current is high, the output frequency increases and vice versa. In controlling the output frequency PID-SVM method has been used. Due to this feedback and output frequency adjustment capacity, the system can run even in very low solar radiation condition.

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